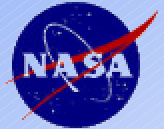# Dual Purpose Simulation: New Data Link Test and Performance Limit Testing of Currently Deployed Data Link

Presentation

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Daryl C. Robinson

NASA Glenn Research Center

216.433.3553

Daryl.C.Robinson@grc.nasa.gov

Aim

- To test a variant of the CSMA Access protocol, PCSMA, in a fairly realistic/robust communications environment in terms of traffic volume and frequency.

- To compare with the known behavior of VDL-2 to see whether PCSMA is a significant improvement.

- To obtain an upper bound for performance of VDL-2 with given traffic.

- To underscore the importance of an efficient access scheme and provide a tool for determining optimum access scheme-performance.

- To establish good baselines or foundations, not only for PCSMA and CSMA, but also for VDL-3 (TDMA) simulations.
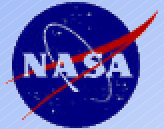
Background

- Lack of surveillance and communications coverage => slow and costly routes.

- Great expected user demand for scheduled air service intensifies problem (3X).

- Solution: Free-flight = operating system giving pilots freedom to select own path and speed in real-time.

- One application is viewed as essential to free-flight (ATC):
  - Controller Pilot Data Link Communications (CPDLC).

- Bandwidth limitations: Narrowband channels and spectrum/freq. shortage

- For probably next 20 years, Very High Frequency Data Link Mode 2 (VDL-2) will be "bread and butter" link.

- VDL-2 uses CSMA, more discussion later.
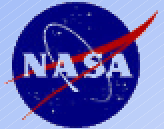
Overview

- All aircraft assumed to use CPDLC over "VDL-2" (PCSMA).

- 1,235 aircraft, 111 ATC ground stations, 32 airports, 32 ATC towers, 24 hours simulated time.

- Realistic communication modeled solely for all incoming and outgoing air traffic originating and terminating at an airport in three cities: Cleveland, Detroit, and Cincinnati.

- 29 (= 32 – 3) airports across the country are sources or destinations of that air traffic.

- Ignores weather and terrain, assumes perfectly spherical earth.

- Since "the MAC layer is especially important in LANs," simulation solely captures CSMA aspect of VDL-2's behavior as well as its radio frequency assignment.
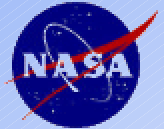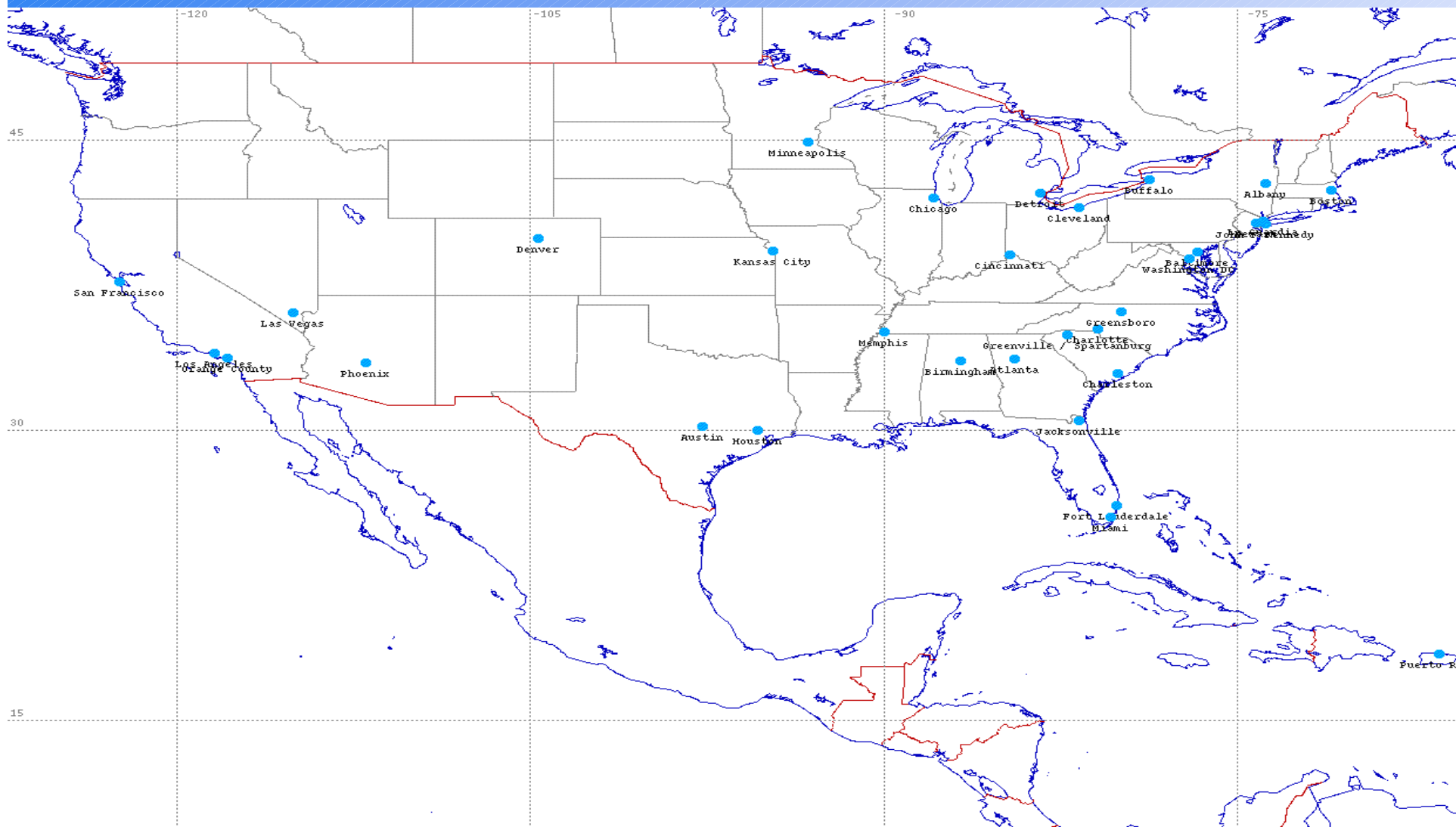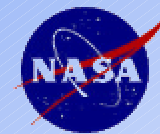
Overview, cont'd.

- CPDLC modeled as unreliable.

- Measures latency and packet loss.

- Simulated CPDLC messages size: 5000 bit mean, normal distribution;

- 6, 3, and 1.5 minute mean interarrival time/simulation, exponential distribution.

- Actual standard CPDLC packet size = 8312 bits.
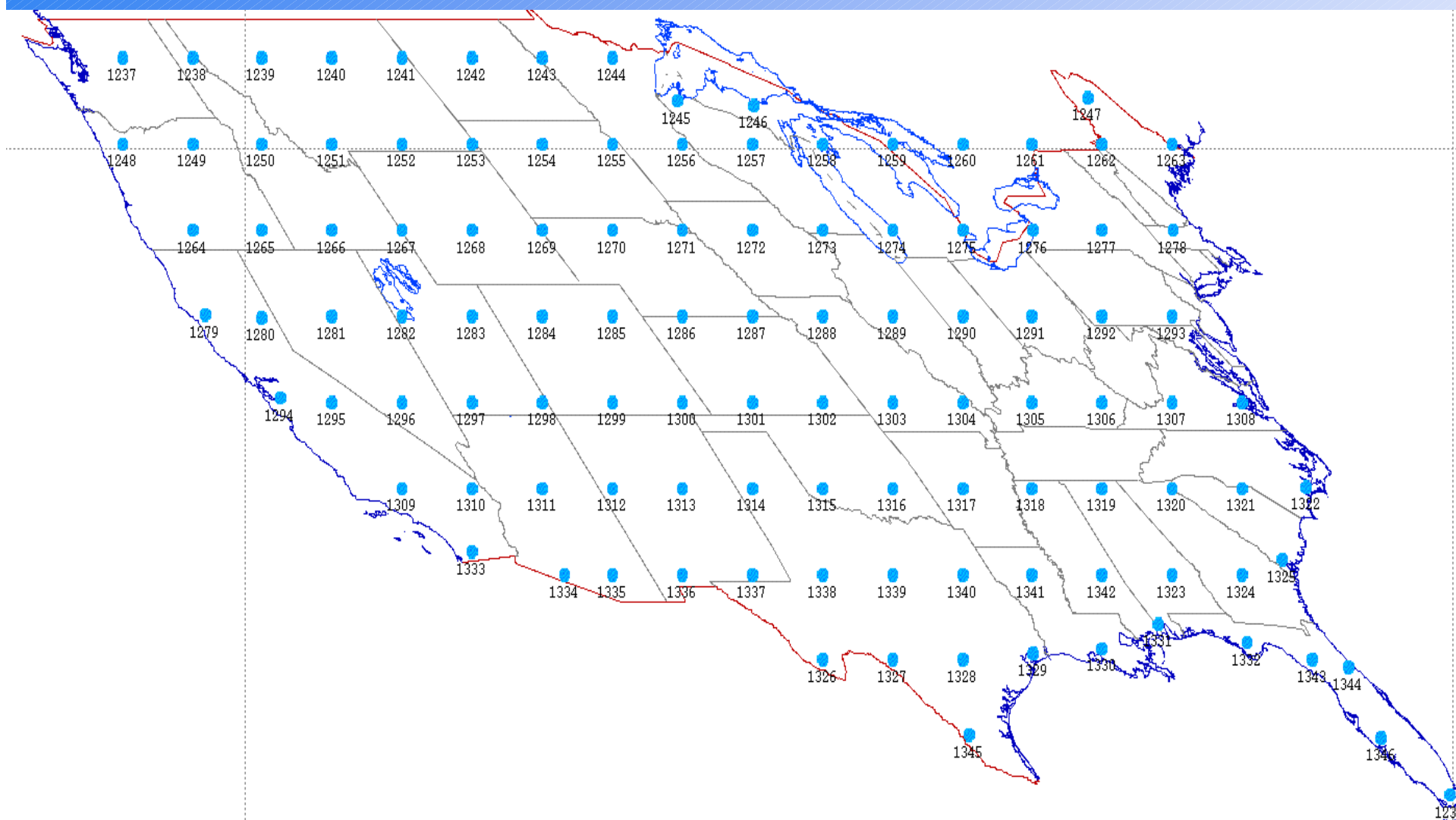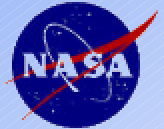
- All CPDLC transceivers at 136 MHz. (VHF)
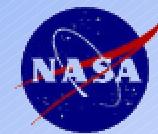
32 Actual Airports

111 Uniformly Distributed Ground Stations

CSMA Discussion

- Listen first; if channel silent, then begin to speak.

- One frequency used, which conserves spectrum.

- Only one station "talks" at a time.

- If two stations within LOS talk at the same time, a collision occurs; once sensed, the stations back-off a random time before attempting to talk again.

- Contention (collisions) make CSMA very inefficient.

- Operators of datalink type services need not wait to speak, pilot types a request and the machinery determines when to transmit.
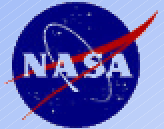
Prioritized (collision-free) CSMA

- Establish a second "common" channel which carries tiny information packets

- Information packets convey station intent to talk data, such as check-in time or queue length.

- Transmission priority on first come, first serve basis.

- When medium busy, each transmitter receives waiting ticket, when free, each takes its turn sequentially.

- Through use of tiny information (cnctrans) packets on a second frequency, each node knows who transmits next.

- When channel is free, no contention, no collisions.
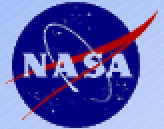
How Prioritized CSMA Works

- Each node broadcasts a zero-length information "cnctrans" packet containing a unique "srcid" code, timestamp, and the queue length of that node.

- When a node receives a cnctrans packet, it updates an array including its neighbors' transmission priority.

- If a cnctrans packet from a node has not been received in time, it's assumed unreachable.

- When a node seizes channel, all nodes wait until it's finished, next node begins orderly transmission.
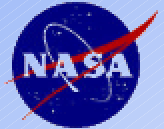
How Prioritized CSMA Works, cont'd.

- Cnctrans packets don't collide since they're small and each node is assigned a unique phase lag with which to broadcast them.

- Just as truckers on opposite sides of the country use the same CB radio frequencies to talk without inter-ference, so different LOS groups can communicate on same frequencies simultaneously without inter-ference.
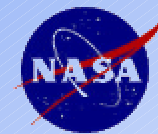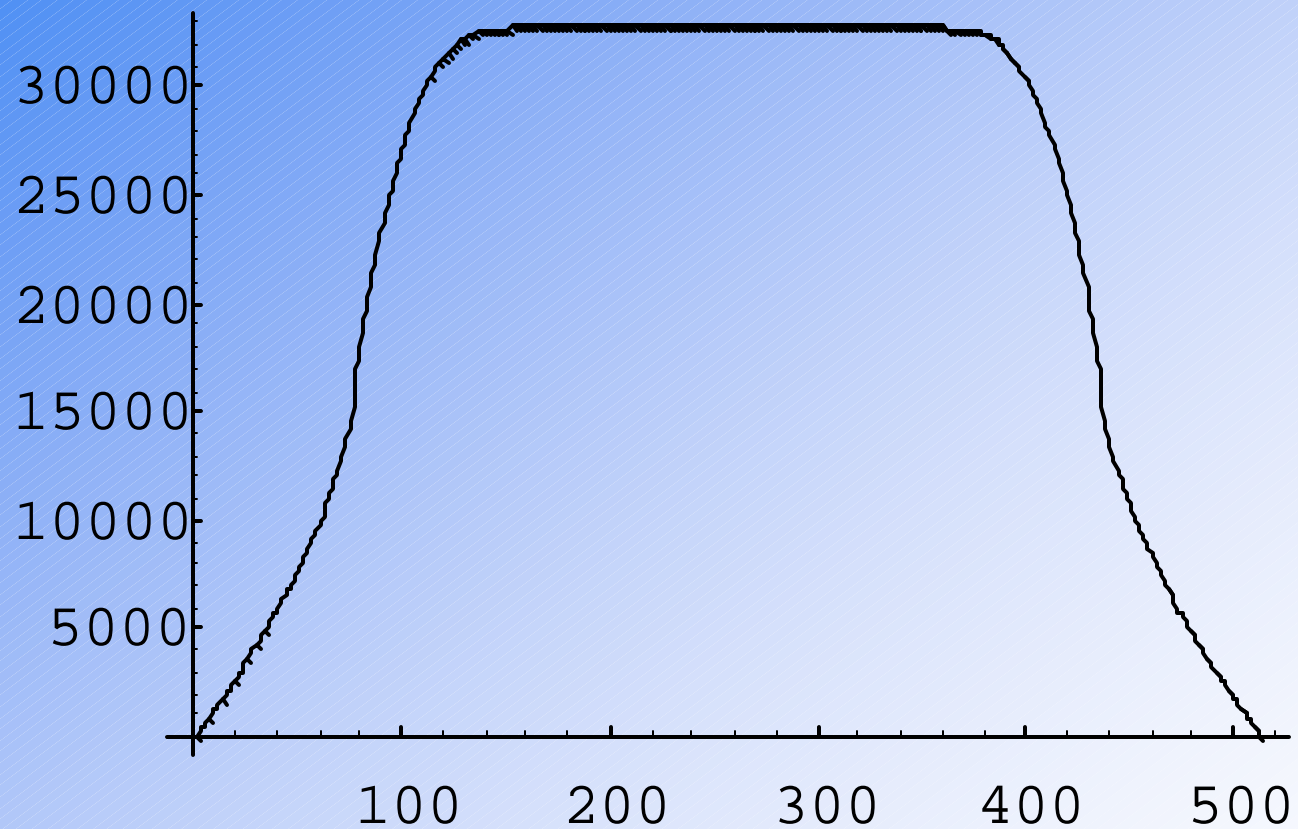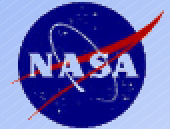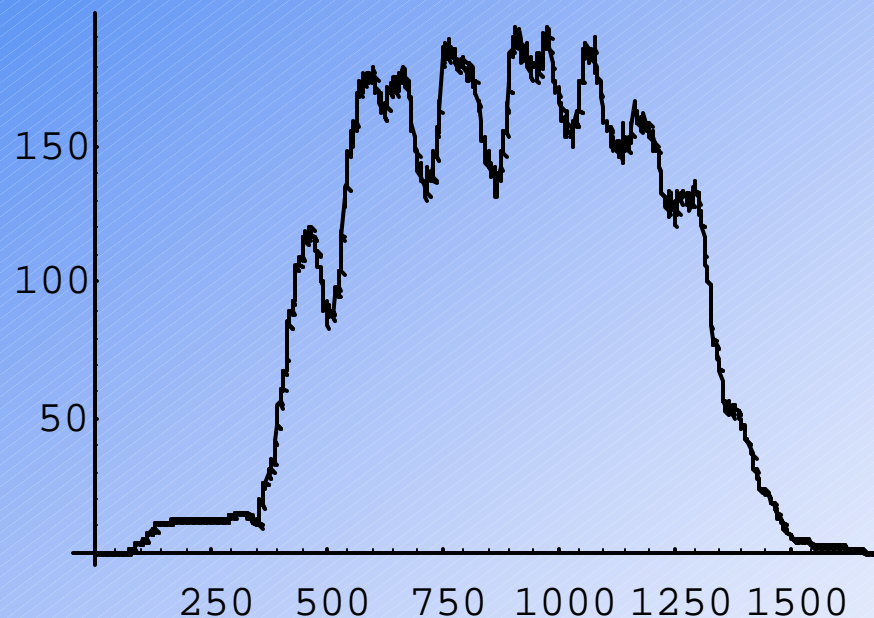
CPDLC Node Architecture
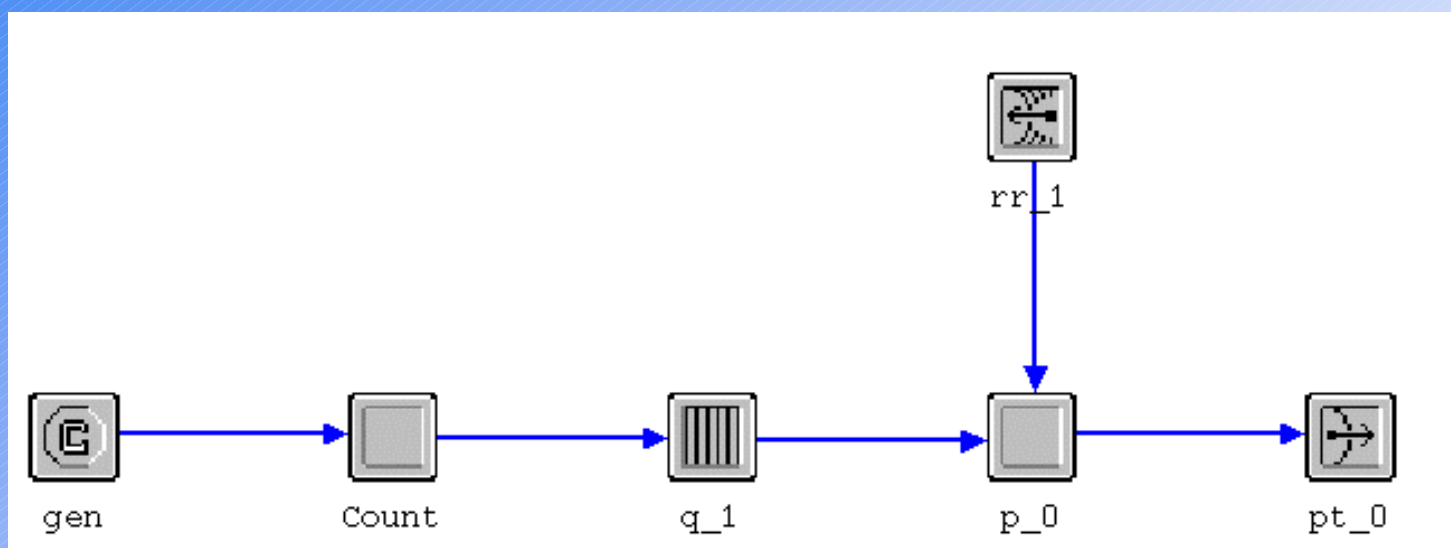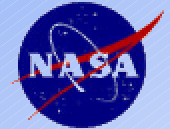
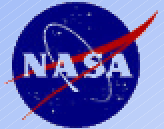# Sample Aircraft Trajectory (ft. vs. sec/10.)

Planes Aloft vs. Time of Day (min.)

- The average number of planes flying is 90.8.

- Peak traffic is at (60 s/min) (910 min.) = 54,600s, or 3:10 p.m.

- From actual airport data.

Simulation Runs

- There were six simulation runs (I –VI),
- I & IV : 6 minute mean CPDLC interarrival time.
- II & V : 3 minute mean CPDLC interarrival time.
- III& VI: 1.5 minute mean CPDLC interarrival time.
- "X" = No Access Scheme. All transceivers set at 31.5 Kbps.
- "D" = Mean ETE delay of CPDLC packets.

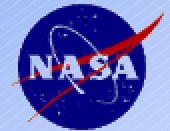I: X, D = 0.3182 s. (T,R) = (38412,34012)
II: X, D = 0.3184 s. (T,R) = (77760, 61807)
III: X, D = 0.3188 s. (T,R) = (156512,104252)
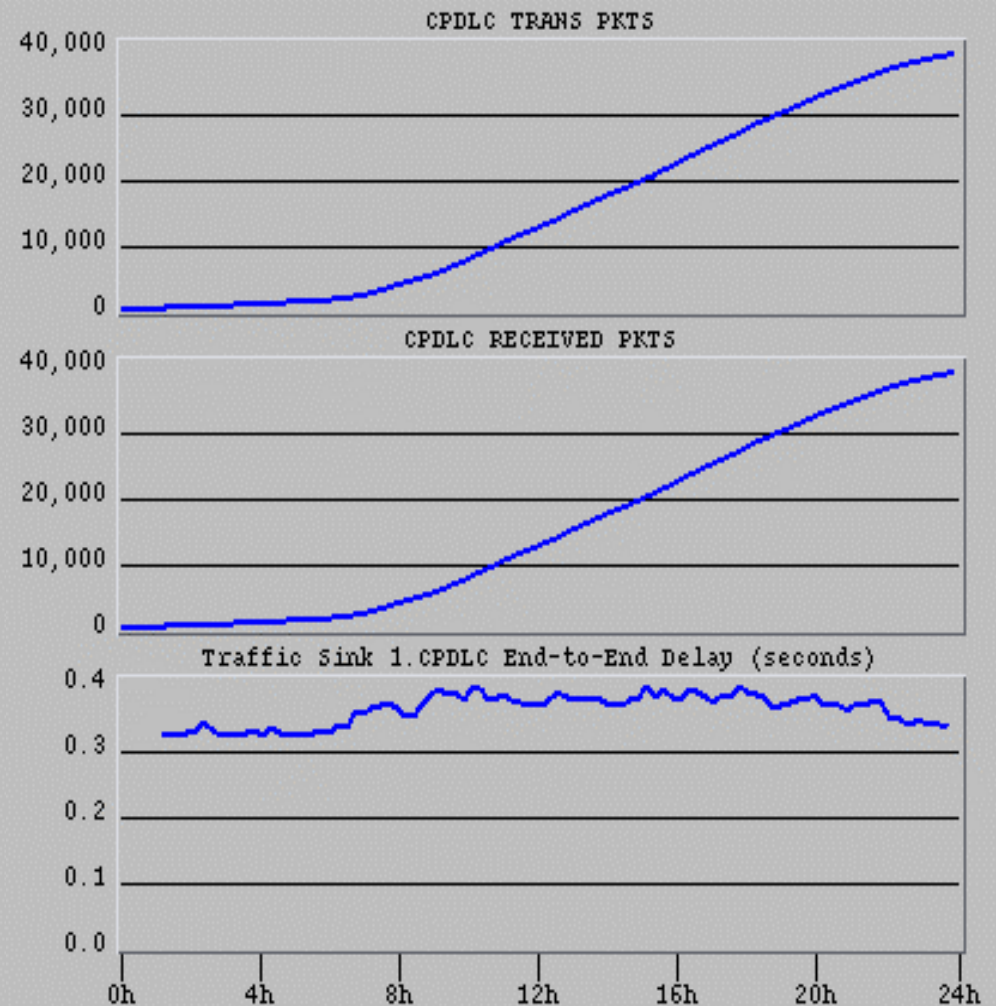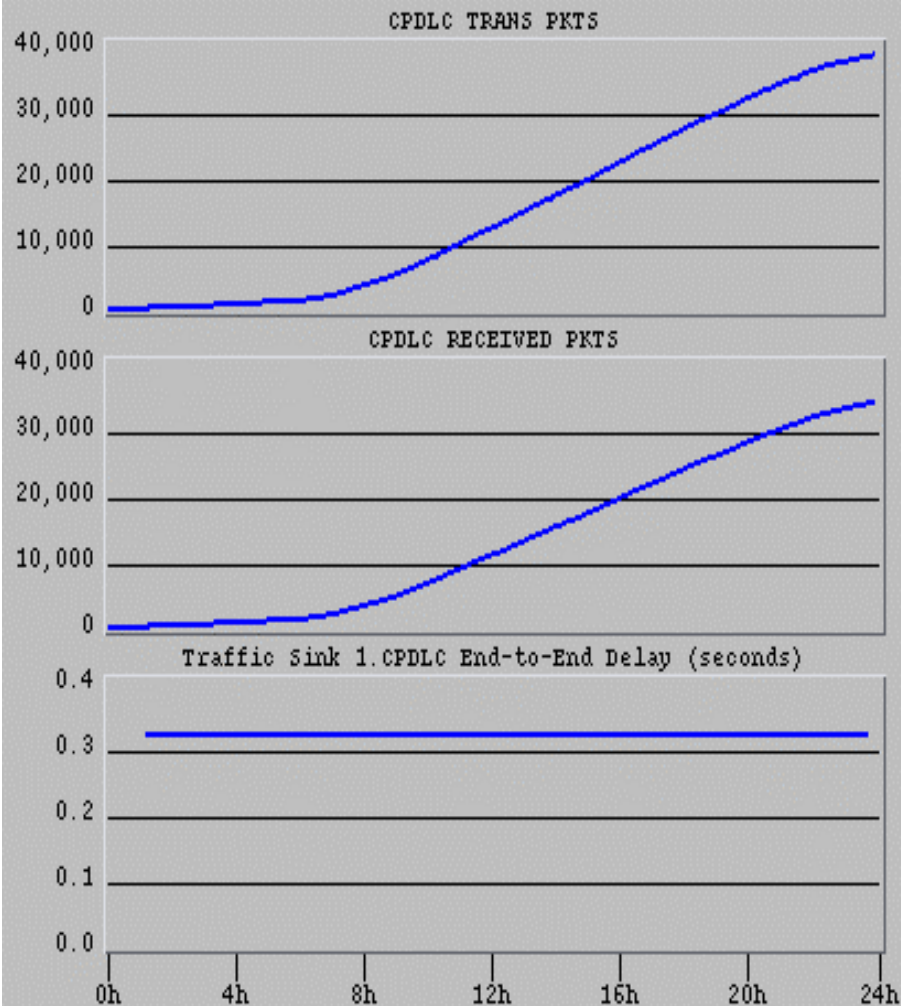**
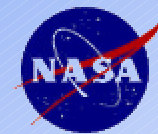
IV: PCSMA, D = 0.3582 s. (T,R) = (38529,38529)
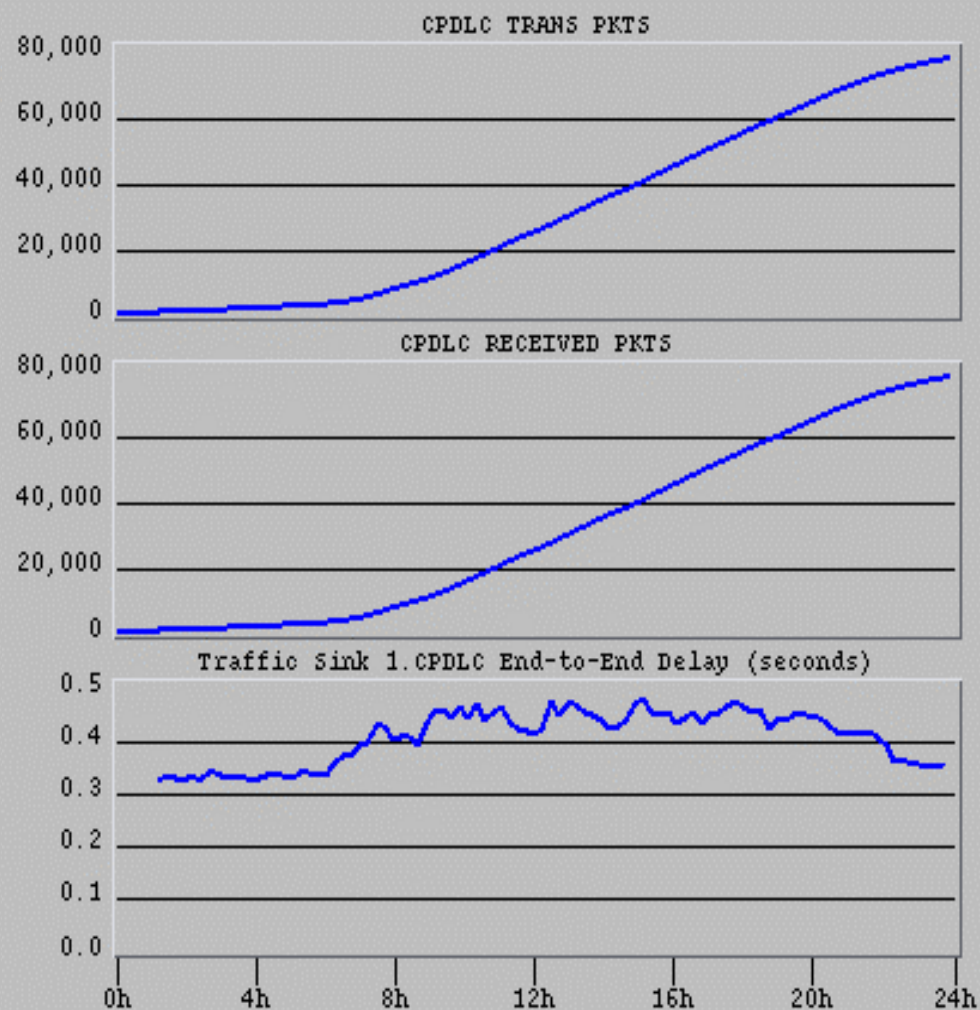V: PCSMA, D = 0.4039 s. (T,R) = (77140,77140)
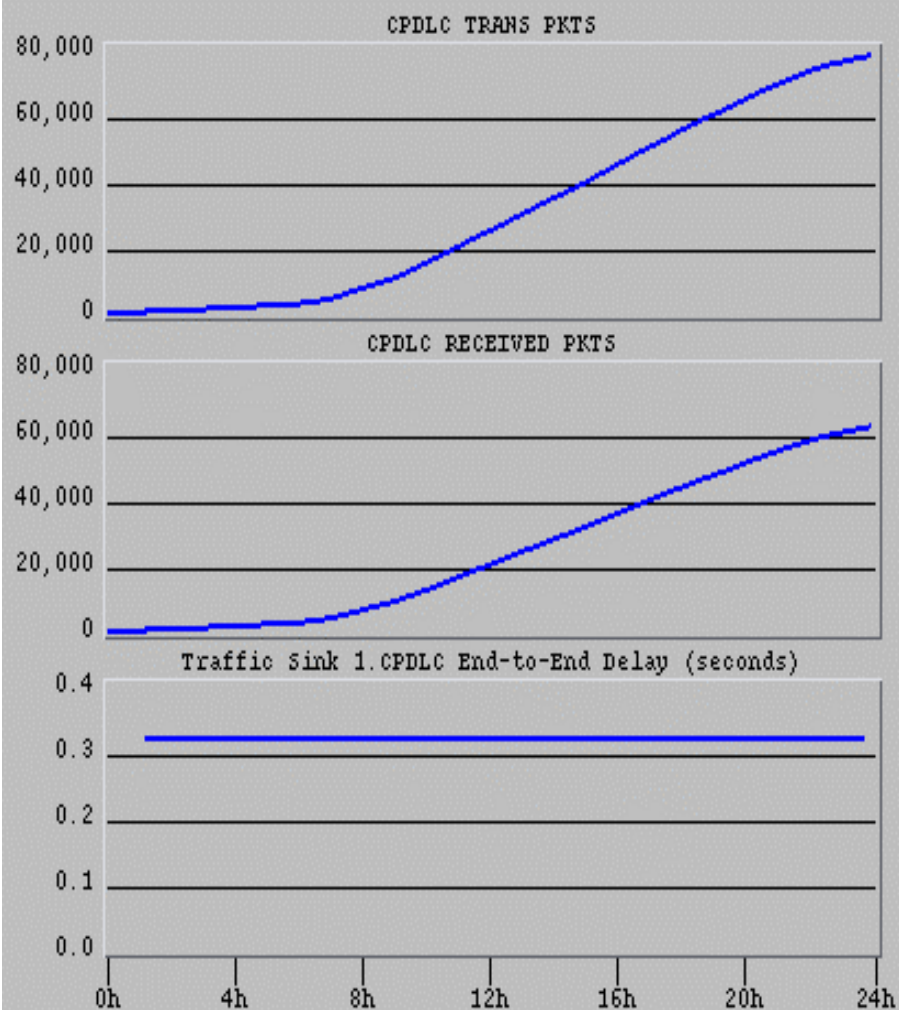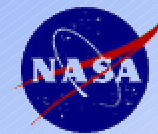VI: PCSMA, D = 0.5772 s. (T,R) = (154304,154304)
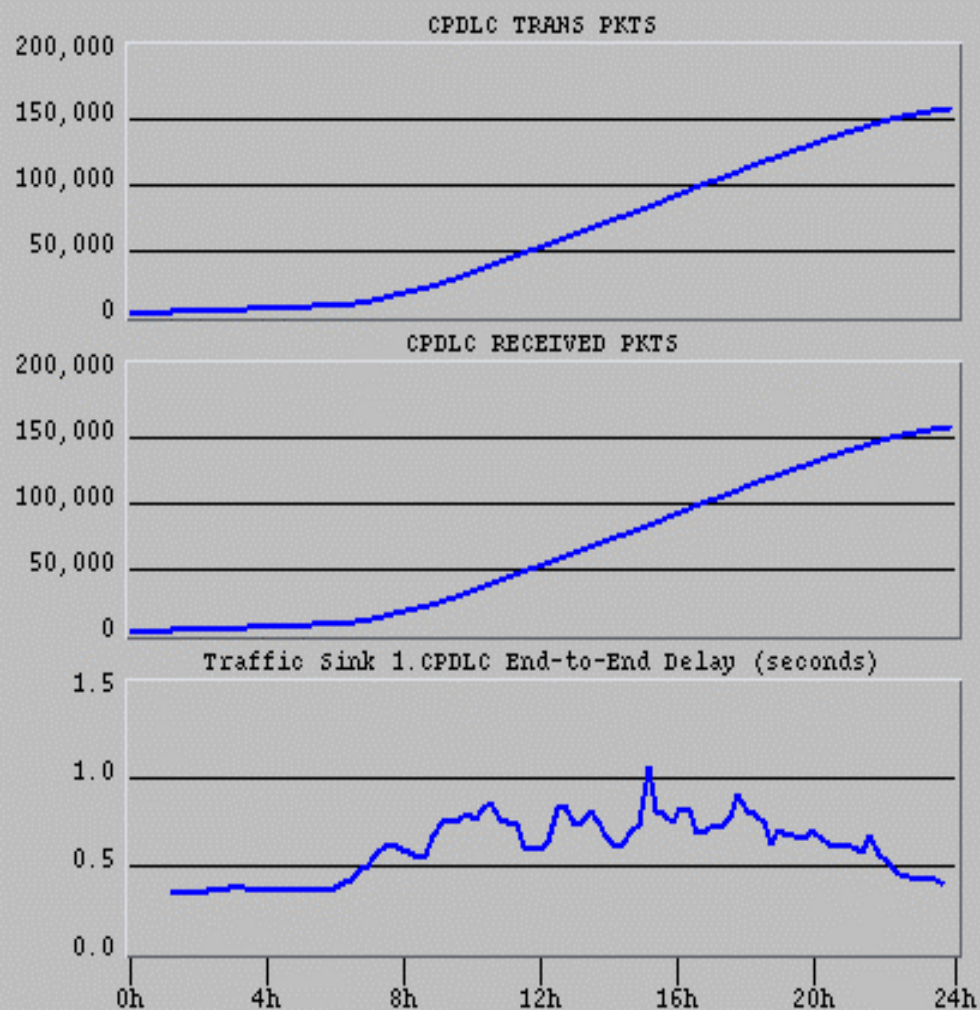
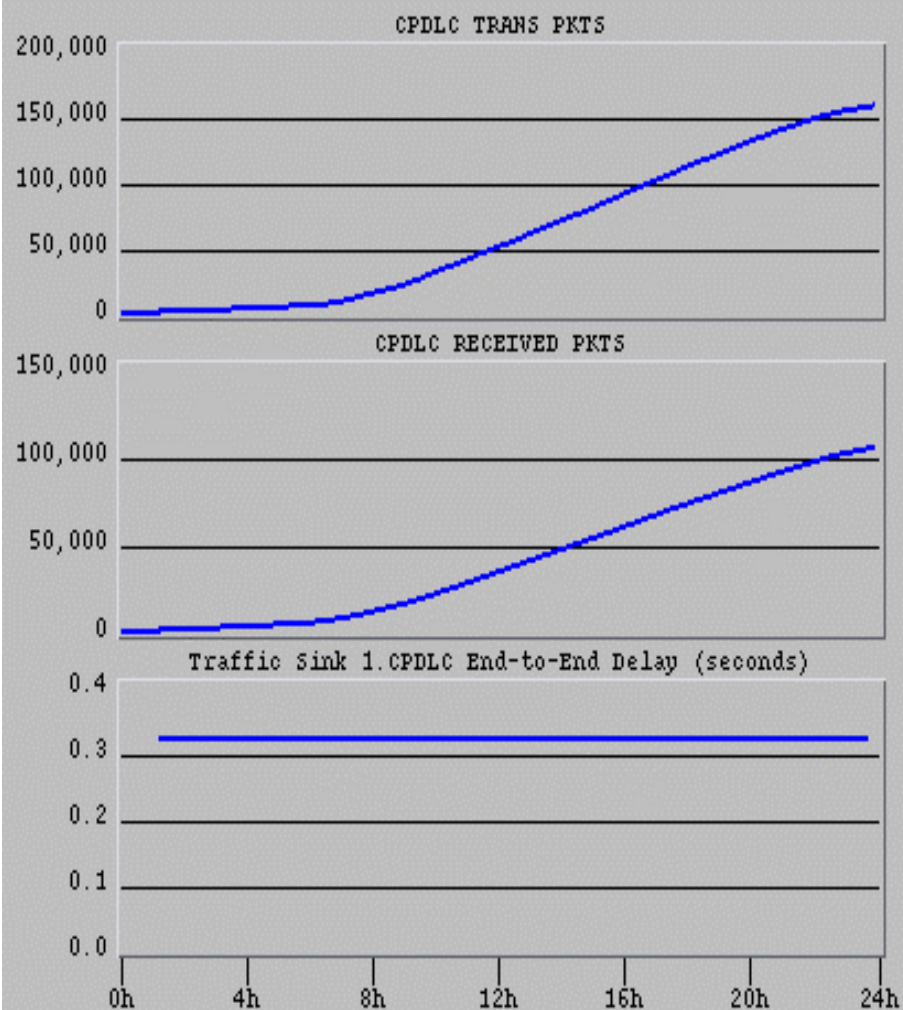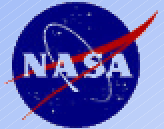# ETE Delay (I & IV, D = 0.3182 s, D = 0.3582 s)

ETE Delay (II & V, D = 0.3184 s, D = 0.4039 s)

ETE Delay (III & VI, D = 0.3188 s, D = 0.5772 s)

Analysis

- A retransmission analysis reveals that if D is the mean ETE delay for a PCSMA network, then D' > D/(1 – p) is the mean ETE delay for a CSMA (VDL-2) network, where "p" is the overall probability of a collision.

- "p" for simulations (I – III) is 11.4%, 20.5%, and 33.4%, yielding respective delay improvements over a comparable VDL-2 simulation of at least 12.9%, 25.8%, and 50.2%.

- A similar analysis involving 90 planes converging on a single ground station reveals that PCSMA gives a minimum of 20% delay improvement over VDL-2.

- Prioritized CSMA works and is probably comparable, if not better than, VDL-3 in terms of latency performance.
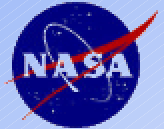
Future Research

- A large network has been constructed for this simulation.

  It may also be used for a simulation of VDL-3, which may be compared to these baseline simulations of PCSMA.

- A smaller CPDLC message size of 5,000 bits was used so that much higher data frequencies could be used and still obtain reasonable latencies.

- Plans are underway to expand the number of daily flights to between 5,000 and 10,000, and to use more precise message sizes and frequencies.

- We intend using versions of this network as a foundation for simulations involving ground station gap analysis and resolution through satellite communications.